S. HRG. 109–446

WEATHER MODIFICATION AND S. 517, THE WEATHER MODIFICATION RESEARCH AND TECHNOLOGY TRANSFER AUTHORIZATION ACT OF 2005

HEARING

BEFORE THE

SUBCOMMITTEES ON: SCIENCE AND SPACE; DISASTER PREVENTION AND PREDICTION

OF THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION
UNITED STATES SENATE

ONE HUNDRED NINTH CONGRESS

FIRST SESSION

NOVEMBER 10, 2005

Printed for the use of the Committee on Commerce, Science, and Transportation

U.S. GOVERNMENT PRINTING OFFICE
28–211 PDF WASHINGTON : 2006

For sale by the Superintendent of Documents, U.S. Government Printing Office
Internet: bookstore.gpo.gov Phone: toll free (866) 512–1800; DC area (202) 512–1800
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WEATHER MODIFICATION AND S. 517, THE WEATHER MODIFICATION RESEARCH AND TECHNOLOGY TRANSFER AUTHORIZATION ACT OF 2005

THURSDAY, NOVEMBER 10, 2005

U.S. SENATE,
SUBCOMMITTEES ON: SCIENCE AND SPACE; DISASTER PREVENTION AND PREDICTION,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
Washington, DC.

The Subcommittees met, pursuant to notice, at 2:30 p.m. in room SD–562, Dirksen Senate Office Building, Hon. Jim DeMint, presiding.

OPENING STATEMENT OF HON. JIM DEMINT, U.S. SENATOR FROM SOUTH CAROLINA

Senator DEMINT. Good afternoon. Sorry for the confusion. I appreciate all of you folks joining us this afternoon and look forward to hearing from you. My other chairman of this meeting, Senator Hutchison, will be back in just a moment. And I know she's been a part of inviting this group here today.

I am very interested in the testimony. We saw, numerous times this summer, and just this past weekend, in Indiana and Kentucky, that weather has a profound impact on the lives of Americans. And this afternoon, the Subcommittees will be discussing weather modification, and, specifically, legislation introduced by my colleague, Senator Hutchison, Senate bill 517, the Weather Modification Research and Technology Transfer Authorization Act.

As I understand, the genesis of this legislation was to help provide relief to drought-stricken farmers in West Texas and across the Nation. As we are all aware, weather modification technologies have been pursued for a number of years. For decades, the Federal Government has dedicated significant resources to weather modification research, and State and local governments continue to spend millions on both operational weather modification technologies and weather modification research.

I was interested to learn that recently the National Research Council of the National Academies, the Nation's leading scientific body, raised some concerns about efficacy of weather modification research. Because of the importance of this issue, I'm looking forward to Dr. Garstang's comments this afternoon and his assessment of the state of the science surrounding weather modification research. It's entirely possible that, at some point in the future,

weather modification technologies might be viable. I continue to be impressed by the progress of all kinds of American innovations. At some point, this Committee may get to the point where it is considering the complex legal, social, and political issues surrounding whether or not the Nation should support a regimen of weather modification. But I am aware there are serious concerns about pursuing a regimen of intentional weather modification and want to give those concerns careful consideration.

I'm also concerned that, as a Nation, we do not have sufficient understanding of how our atmosphere behaves. It seems that this may be a concern shared by the Academy, noting some of the findings in their recent report. I think this Committee should give thoughtful consideration to their principal conclusion, which stated that, "Atmospheric science is now in a position to mount a concerted and sustained effort to delineate the scope and expectations of future weather modification research. Such an effort must be directed at answering fundamental scientific questions that will yield results that will go well beyond application to intentional modification. The emphasis must be on understanding processes, and not on modification." I think—in other words, I believe what I'm hearing them saying is that we need to understand how weather works now before we go too far in trying to modify it.

I would also encourage the scientific community, and particularly the atmospheric-sciences community, through the National Academies or our scientific societies, to decide what are the highest priorities and most promising areas of research for fundamental atmospheric research. The NRC report on weather modification research outlines some areas that may inform weather modification, such as precipitation physics and cloud modeling. Could these areas or other areas of the research be considered as part of a comprehensive program of atmospheric research? I'll let you answer the question today.

Priority-setting is going to be important. In recent years, Republicans in Washington have endeavored to constrain Federal spending. We've not been as successful as I would like, but I'm committed to working with my colleagues to ensure that Federal discretionary spending not only does not grow, but that it shrinks.

I say all this to encourage the atmospheric-science community to think critically about where you want to put the next dollar in atmospheric research. There are some very promising places to put this funding that could have a dramatic impact on the lives of all Americans. I would encourage you to consider the various research initiatives proposed by the Academy in light of the other important initiatives that need to be undertaken to improve prediction of tornado formation, to understand the rapid intensification of hurricanes, and the other challenges facing us.

How do all of these competing priorities interact? Maybe there is some overlap that will address these important issues and inform weather modification. I hope the scientific community can help me and this Committee with this priority-setting.

This Committee is committed to advancing atmospheric sciences, because we understand what an important role weather plays in the lives of all Americans. So, I'm looking forward to hearing from

you. This issue leaves me with a lot of questions, and I'm hoping my witnesses can answer some of those questions today.

Appearing this afternoon is Dr. Joe Golden, Senior Research Scientist at Colorado's Cooperative Institute for Research in the Environmental Sciences. Dr. Golden previously directed NOAA's weather modification research programs. He will discuss Senate bill 517 and its potential benefits for weather modification.

Also with us is Dr. Tom DeFelice, past President of the National Weather Modification Association. He will be providing perspectives on the importance of weather modification and weather modification research.

Finally, appearing before the Subcommittees this afternoon, is Dr. Michael Garstang. Dr. Garstang is a Distinguished Emeritus Research Professor in the Department of Environmental Sciences, at the University of Virginia. He's a fellow at the American Meteorological Society, the AMS—and has served on numerous AMS committees. He was also the Chair of the 2003 National Research Council Committee on Critical Issues in Weather Modification Research.

OK, having introduced all of our panelists, Dr. Golden, we'll start with you, and if Senator Hutchison comes in, we may need to take a break and let her make a statement if she can't stay the whole time.

So, Dr. Golden, please—I think we're going to try to keep this to five minutes, and then some questions.

STATEMENT OF DR. JOSEPH H. GOLDEN, SENIOR RESEARCH SCIENTIST, COOPERATIVE INSTITUTE FOR RESEARCH IN THE ENVIRONMENTAL SCIENCES (CIRES), UNIVERSITY OF COLORADO

Dr. GOLDEN. Thank you, Senator DeMint.

I am honored to appear before you today in regards to Senate bill 517, the Weather Modification Research and Technology Transfer Authorization Act of 2005. My name is Dr. Joseph Golden, retired from NOAA on September 2, 2005, after over 41 years of Federal service in NOAA, both in severe-weather research and NWS operations. I now work part-time as a Senior Research Scientist in the University of Colorado's Cooperative Institute, in Boulder, Colorado.

My background in weather modification research relates to the fact that I was the last NOAA manager of the Atmospheric Modification Program, or AMP, in NOAA research until its termination by the Congress in 1995. None of the NOAA AMP funds were used to conduct any operational cloud-seeding, and I feel that, at this time, funding under Senate bill 517 should also not be used to conduct any operational cloud-seeding.

The Texas participation in my AMP program was the first to utilize the NWS NEXRAD Doppler radar data to estimate the rainfall increases from seeding convective clouds in Texas. However, one of my greatest career frustrations has been witnessing the adoption of new research results and technologies, that we developed under AMP, by other countries, while our Federal research and technology transfer in my country has largely stagnated.

One example, a chemical tracer technique that we developed in my Nevada AMP program to quantify the amount of snow increase due to seeding over mountains is now being used by a new cloud-seeding program in Australia.

In China alone, their government is now funding a greatly expanded weather modification research and operations program at $100 million per year, as well as training over 1,500 new weather modification scientists.

Federal funding for weather modification research in the United States reached its pinnacle in the 1970s and early 1980s, and has steadily declined ever since. During its heyday, weather modification research in the U.S. was at the cutting edge of worldwide efforts. For example, NOAA conducted large-scale seeding experiments, in South Florida, called FACE, and we collaborated with the Navy and university scientists in Project STORMFURY to weaken hurricanes. I participated in STORMFURY while I was a Ph.D. candidate, and found it to be one of the most exhilarating experiences of my career.

The need for a renewed national commitment and funding for weather modification research has become more urgent, in my view. In recent years, we have seen severe drought in my home State of Colorado and the Pacific Northwest. New research results show unmistakable impacts of air pollution in reducing seasonal precipitation over mountainous areas of the Western U.S. during the past several decades. Pollution is systematically robbing the western mountains of winter snowpack, and, if the process continues, will lead to major losses of runoff water for hydroelectric power and agricultural crop productivity. However, research results in Israel—has demonstrated that their long-term cloud-seeding programs have offset similar pollution-induced rainfall losses in their country.

Another weather modification research issue, and one that elicits scientific controversy, is severe-storms modification. I don't have time to go into this in any depth, but one of the longest-running hail-suppression programs in the world is in North Dakota. And, during my tenure, AMP sponsored their research. Positive results on the impact of cloud-seeding to reduce hail damage to crops using insurance companies' records of crop-loss ratios were so impressive in North Dakota, that the Canadian insurance industry has supported a new multi-year effort in the Province of Alberta, Canada, to protect its largest cities from hail. The Alberta hail-suppression program uses many of the techniques that we used in the AMP North Dakota program.

Finally, after the horrendous devastation and loss of life from Hurricanes Katrina and Rita, I have been asked several times about the possibility of hurricane modification. And, while we don't have time to fully address the issue today, I firmly believe that we are in a much better position, both with the science and the undergirding technology, than we were when Project STORMFURY was terminated by our government in 1982. We now understand that both tornados and hurricanes exhibit a life cycle, and both exhibit natural instabilities during their lifetimes.

Even after the demise of the AMP program in 1995, operational weather modification programs have continued to expand and

flourish in the U.S. This is reflected in the annual reports of all such projects to NOAA, as required by law.

I like the idea of establishing a Weather Modification Advisory Board with broad representation, which is needed to set the national agenda and priorities, as Senator DeMint has already touched upon, for these and other urgent water-management issues facing the country. I have many close scientific colleagues in NOAA weather research who would welcome the opportunity to contribute to a reinvigorated national program of weather modification research and technology transfer.

In closing, I want to assure you that the U.S. has the technology and the best and brightest scientists, who would welcome the opportunity to reinvigorate the weather modification field. These are very challenging issues, and the worsening water crises in the West and elsewhere demand our urgent attention.

Thank you.

[The prepared statement of Dr. Golden follows:]

PREPARED STATEMENT OF DR. JOSEPH H. GOLDEN, SENIOR RESEARCH SCIENTIST, COOPERATIVE INSTITUTE FOR RESEARCH IN THE ENVIRONMENTAL SCIENCES (CIRES), UNIVERSITY OF COLORADO

I am honored to appear before you today in regards to S. 517, the Weather Modification Research and Technology Transfer Authorization Act of 2005. My name is Dr. Joseph H. Golden, retired from NOAA on September 2, 2005 after 41.5 years of Federal service in NOAA, both in severe weather research and NWS operations. I now work part-time as a Senior Research Scientist in the University of Colorado's Cooperative Institute for Research in the Environmental Sciences (CIRES) in Boulder, Colorado. My background in weather modification research relates to the fact that I was the last NOAA manager of the Atmospheric Modification Program (AMP) in NOAA Research, until its termination by the Congress in 1995. I was never asked by anyone to defend the AMP Program, based on its merits and accomplishments. The AMP program was written into NOAA's budget by the Congress for many years, beginning in the late 1970s. I view the AMP program and its research productivity as a highlight of my NOAA career, especially due to the cooperative efforts among the six States in the program (Illinois, North Dakota, Texas, Utah, Nevada and Arizona), the universities, private-sector operators, and NOAA research. None of the NOAA AMP funds were used to conduct any operational cloud seeding, and I feel that, at this time, funding under S. 517 should also not be used for operational cloud seeding efforts. I am pleased to see my colleague, George Bomar here from Texas: he was one of the State program managers in AMP, and his State was the first to utilize NWS NEXRAD Doppler radar data to estimate the rainfall increases from seeding convective clouds. One of my greatest career frustrations has been witnessing the adoption of new research results and technologies we developed under AMP by other countries, while Federal research and technology transfer in my own country has largely stagnated. For example, a chemical tracer technique developed by the Nevada-AMP program to quantify the amount of snow increase due to seeding over mountains is now being used by a new cloud seeding program in Australia. In China alone, their government is funding a greatly-expanded weather modification research and operations program at $100 million per year, as well as training over 1,500 new weather modification scientists.

In the limited time I speak before you today, I want to address two types of natural disasters, and the potential for planned weather modification to alleviate them: slow-onset disasters over many years, such as the continuing drought in the West, and the quick-onset disasters such as the record-breaking Atlantic hurricane season this year and the massive Oklahoma City tornado outbreak of May 1999.

Federal funding for weather modification research in the U.S. reached its pinnacle in the 1970s and early 1980s, and has steadily declined ever since. During its heyday, weather modification research in the U.S. was at the cutting edge of worldwide efforts. For example, NOAA conducted large-scale seeding experiments in South Florida (called FACE) and collaborated with the Navy and university scientists in Project STORMFURY, to weaken hurricanes. I participated in STORMFURY while a Ph.D candidate, and found it to be one of most exhilarating experiences of my ca-

reer. The National Center for Atmospheric Research (NCAR) also organized the National Hail Research Experiment, which attempted to test the validity of the Russian approach to artificially reduce hail by cloud seeding. Finally, the Bureau of Reclamation carried out the High Plains experiment, to seed convective clouds for rainfall increases over the Central U.S. While each of these programs, in my opinion, produced outstanding scientific results and new operational insights, they produced results that were inconclusive insofar as *statistical evaluation* is concerned. Nevertheless, I feel that our community was a good steward and used limited funding very wisely. I am also convinced that the atmospheric sciences have come a long way during the intervening years. The scientific foundation and underlying physics in purposeful weather modification, i.e., cloud seeding, is sound and well-established. We now have both the science and the technology to launch a new research attack on some of these other vexing problems.

The need for a renewed national commitment and funding for weather modification research has become more urgent. In recent years, we have seen severe drought in my home State of Colorado and the Pacific Northwest. New research results show unmistakable impacts of air pollution in reducing seasonal precipitation over mountainous areas of the Western U.S. during the past several decades. Pollution is systematically robbing the Western mountains of winter snowpack, and if the process continues, will lead to major losses of runoff water for hydroelectric power and agricultural crop productivity. However, research in Israel has demonstrated that their long-term cloud seeding programs have offset similar pollution-induced rainfall losses in their country. The new research has also developed new analysis techniques with NOAA satellite data to objectively identify and separate pollution episodes from affected neighboring clouds. The pollution effects on natural precipitation in our country and elsewhere is certainly a critical research issue for this bill. Another issue needing more research attention is the question of extra-area effects: if we seed cloud systems in one area, and successfully produce increases of precipitation there, are we "robbing Peter to pay Paul" in downwind locations? Results supported by AMP suggested the answer is no, and that there is either no effect downwind, or a slight increase in precipitation.

Another weather modification research issue, and one that always elicits scientific controversy, is severe storms modification. This issue was not addressed much in the NAS/NRC weather modification report chaired by my distinguished colleague, Michael Garstang. These are the quick-onset disasters of which I spoke earlier, and include hailstorms, tornadoes and hurricanes like Katrina and Rita this year. I should emphasize that AMP supported some outstanding hail modification research with the North Dakota Cloud Modification Program. This operational program is one of the longest-running hail suppression programs in the world. Positive results on the impact of cloud-seeding to reduce hail damage to crops, using insurance companies' records of crop-loss ratios, were so impressive, that the Canadian insurance industry has supported a new multi-year effort in the province of Alberta, Canada to protect its largest cities from hail. The Alberta hail-suppression program uses many of the techniques that we used in the AMP-North Dakota program.

After the horrendous devastation and loss of life from Hurricanes Katrina and Rita, I have been asked several times about the possibilility of hurricane modification. And while I don't have the time to fully address this issue today, I firmly believe that we are in a much better position, both with the science and the undergirding technology, than we were when Project STORMFURY was terminated in 1982. We now understand that both tornadoes and hurricanes exhibit a life-cycle, and both exhibit natural instabilities during their lifetimes. The key atmospheric condition leading to the decay of both destructive vortices is cooler, drier air, as well as cooling sea surface conditions for decaying hurricanes. Recent observational and modeling studies both suggest that there may be new approaches possible for future weakening or track-diversion of hurricanes threatening our shoreline. The key uncertainty, and one which requires enhanced observations, is more continuous and accurate monitoring of the natural fluctuations in hurricane intensity and path. For example, Wilma intensified in the western Caribbean overnight from a Category 1 to a Category 5 hurricane, resulting in the lowest pressure ever measured in the eye of an Atlantic-basin hurricane. There are now some very exciting computer models that reproduce both hurricane intensification and tornado behavior in remarkable detail. If we mount a sustained, adequately-funded national program of weather modification research and technology transfer, I believe that it may also be possible to successfully weaken tornadoes (or, alternatively, shorten their life-cycles). I would be pleased to elaborate details on promising approaches and testable hypotheses for tornado/hurricane amelioration at some future time. I am presently collaborating with colleagues, Drs. Rosenfeld and Woodley, in testing a new technique for identifying storm systems with high threat of producing tornadoes. This

technique utilizes NOAA satellite data at various wavelengths and shows promise in improving NWS lead-times for tornado watches and warnings.

Even after the demise of the AMP Program in 1995, operational weather modification programs have continued to expand and flourish in the U.S. This is reflected in the annual reports of all such projects to NOAA, as required by law. Most of these projects are supported by the States, utilities or the private-sector. One of my private-sector colleagues recently noted his estimate *of total annual expenditures in the U.S. of $25–30 million* for weather modification operational projects. There is now very little Federally-supporting research to aid these operational programs in evaluation, or improving their technological base. We have some of the best cutting-edge science in NOAA research, NCAR and the universities that can help the private weather modification operators improve their evaluation of seeding effects, as well as improved targeting of seeding materials in suitable cloud systems. I like the idea of establishing the Weather Modification Advisory Board, with broad representation, which is needed to set the national agenda and priorities for these and other urgent water management issues facing the country. I have many close scientific colleagues in NOAA weather research who would welcome the opportunity to contribute to a reinvigorated national program of weather modification research and technology transfer, if support can be found. In fact, our Boulder laboratories won a Department of Commerce Gold Medal for our contributions to the recently-completed NWS Modernization and AWIPS computer workstations. I am one who has long believed, that to be successful in any form of purposeful weather modification, we must first do a very good job of predicting the natural phenomena.

In closing, I want to assure you that the U.S. has the technology and the best and brightest scientists who would welcome the opportunity to reinvigorate the weather modification field. These are very challenging issues and the worsening water crises in the West and elsewhere demand our urgent attention.

Senator DEMINT. Thank you.

Dr. Defelice?

STATEMENT OF DR. THOMAS P. DEFELICE, PAST PRESIDENT, WEATHER MODIFICATION ASSOCIATION

Dr. DEFELICE. I am honored to appear here today in regards to Senate bill 517.

My name is Dr. Tom DeFelice. I have two degrees in atmospheric science, bachelor's in—and Ph.D., and a master's in atmospheric physics.

I was the WMA President—"WMA" stands for the Weather Modification Association—President for 2 years, between 2000 and 2002. I'm now the Chair of the WMA Public Information and Outreach Committee. I began the process before you today by engaging a retired State Senator from Texas, John Leedom, who then engaged Senator Hutchison and her staff.

My experiences and the literature demonstrate that weather modification technologies generally possess the potential to increase the rainfall when applied under appropriate conditions. I don't have time to go into all the details of those conditions, but will gladly take some questions later.

The scientific and operational communities generally agree that the recent advances in the relevant general physical processes and technologies used to assess those processes come together and form the basis for the need to have a sustained national program to carry out basic and applied research in weather modification sciences. This happens to be one of the main recommendations of the Garstang report.

Basically, I see Senate bill 517 as the next logical step as one could derive from the Garstang report. It is about research and development of technologies. But it's not just any research and any development; it is research and development that could ultimately

be used to produce a product that could help everybody. It could help commerce, improve better forecasts of the weather, which could then help our agricultural entities better plan their crops, for example. It could help science by improving their models, improving our understanding of processes, especially those of hurricanes, to understand why hurricanes like Katrina could form, for example. But it also could reinvigorate education. It could help transportation by planning for certain weather events that we may or may not be able to detect, or take for granted—freezing rain, icing of roads, for example. Predicting and mitigating adverse weather conditions in these cases would have a great benefit, not only to lives, but also to our economies. It could also help airports in certain circumstances, particularly during the winter, by clearing out fogs.

Technology could benefit, since the results, information from this bill could be another application directing its innovators and be used to transfer said information to the public. So the research from this bill could also help the people. And that's what it's all about. Because the people are faced with an impending water shortage. By the decade of the 2020s, our models predict that 40 percent of the world's population are going to be living in drought-stressed areas. And we need to start doing something now about that, because if we wait, it will be too late, because we haven't been doing the research to develop and to make sure we have all our ducks in a row, all our technologies up to par, so that they could be of some more use (for those that are not useful already). We need to do something about this, because 8 percent of the total water budget on the globe is due to consumption, and only 1 percent of the water budget is currently an input. That's rain. Now, with global warming—and the results of that are predicted to minimize precipitation falling to the ground—that means by the decade of the 2020s, or shortly thereafter, less than 1 percent of the total water budget is going to be an input. That means we're—and with the population growing, we're going to consume more water, so we're going to have a really, really grave and—how do I say it?—big problem on our hands, because, well, there won't be enough water to feed our crops.

And so, I strongly urge everybody—on this Committee and elsewhere—to consider passing this bill and bringing it to its companion bill in the House.

[The prepared statement of Dr. DeFelice follows:]

PREPARED STATEMENT OF DR. THOMAS P. DEFELICE, PAST PRESIDENT, WEATHER MODIFICATION ASSOCIATION

I am honored to appear before you today in regards to Senate bill 517, the Weather Modification Research and Technology Transfer Authorization Act of 2005. My name is Dr. Thomas P. DeFelice. My background in weather modification began when I was 15 by reading books on the subject; I had many sessions with WMA forefathers Schaefer & Vonnegutt as an undergrad; my academic and subsequent professional career concentrated on learning the fundamentals of weather modification relevant sciences and its technologies; President of WMA (2000–2002), Chair WMA Public Information Committee (since 2004). I now work as the contractor program manager for two NOAA programs. I am here on my own behalf, expressing my own beliefs. I began this process, engaged John Leedom, who engaged Senator Hutchison & her staff, and here we are today.

Weather modification technologies are key to dealing with many present and potential future scientific, environmental, and socioeconomic issues like steadily increasing human suffering and property damage caused by hazardous weather (e.g.,

severe weather-Katrina, supercooled fog, freezing rain), fire, and other environmental problems related to "acid rain," biological or chemical warfare, for instance. Their application generally increases rainfall amount. Rain contributes 1 percent of the total global water budget. Global water consumption presently makes up 8 percent of the total global water budget. Models estimate about 40 percent of the world's population will live in water—stressed areas by the decade of the 2020s and consumption will increase. Further, air pollution (global warming) is reported to reduce the amount of rainfall. Hence, a need to develop new technologies, while applying proven techniques. Water rationing and water management techniques are useful, they do not replenish the reduced rainwater amount. (They simply put a small band-aid on a wound that requires multiple stitches.) Therefore they fail to resolve the issues' root cause. Alternatively, weather modification technologies increase the rainfall amount (compared to normal) under certain conditions. (They simply put multiple stitches on a wound that requires multiple stitches.) Therefore weather modification technologies can resolve the issues' root cause, which will be ensured through the research and development program set up by passing S. 517 and its companion bill (H.R. 2995).

Yet some retain an issue concerning whether operational cloud seeding activities, especially associated with convective clouds, achieved the intended results claimed. Additional evaluations should pacify this issue, especially with the recent technological advances. This would also help us answer, are weather modification technologies ready to increase water resources and alleviate, or possibly prevent drought. Yes, they are ready to increase water resources under certain cases, based on the available 60-year literature archive, and first-hand information. S. 517 provides a research and development infrastructure for a program that addresses and ultimately resolves these issues, while nurturing and developing these technologies to provide better returns on our investment.

The scientific and operational communities generally agree that the recent advances in the relevant, general physical processes and technologies need to be capitalized upon in the form of a concerted and sustained national program to carry out basic and applied research in weather modification (e.g., Garstang report, Orville report, NRC). However, the perceptions between the science and operational communities differ, namely, (1) Interpretation of scientific proof, (2) Current status of cloud models as applied to weather modification, (3) Evidence of glaciogenic seeding in convective clouds, (4) Cold season orographic seeding, (5) Evidence for hail suppression, and (6) Support for specific purposes. The cold season orographic seeding perceptual difference (4) is not a significant difference in perspective, since the science community (post Garstang report) sees orographic cloud seeding as a particularly promising candidate for an intensive field program.

Perceptual difference (6) reflects the differences between the individual cultures (i.e., scientific versus operational) than anything else. Nonetheless, no implementation plans have been proposed.

I summarize an implementation plan for S. 517 for consideration by its Weather Modification Board, which addresses all issues. This implementation plan is born from sound scientific basis derived from 60 years of lessons learned exercises, recent technological advances, and science community recommendations (Garstang report, Orville report, NRC). Societal need provides an impetus for developing systems and technologies that monitor and manage atmospheric events, the creation of a new weather modification research program and implementation plan according to standard engineering practices. This plan helps mitigate the perceptual diferences by setting up an integrated team approach to its activities, and by insisting that its research and development component be geared toward improving the effectiveness of operations.

It calls for administering the resources and the activities for all research and development efforts directed toward optimizing the technologies used to manage atmospheric processes and their resultants (e.g., collision-coalescence, hurricanes, orographic and convective precipitation, frozen rain). Its mission would be to develop the technologies used for operational activities that help provide sustainable water supplies and reduce airborne hazards. This includes improving the understanding of the relevant processes and their simulations, as well as the evaluation methods (physical; chemical; statistical-random, non-random) for operational activities through cooperative multidisciplinary research and development arrangements and a well-designed outreach effort. Further development is needed for successful application of weather modification technologies to mitigate hurricane and tornado damage, minimize the negative affects of anthropogenic air pollution on precipitation efficiency, or to neutralize negative effects from pollutant deposition. Such requires a modeling approach, then verification, and transition to operational use.

The modern weather modification technologies applied to disperse supercooled fog, augment the ice crystal process in cloud systems, especially orographic clouds, are very effective. Statistical reanalysis using 50+ years of Sierra data show strong signals that the seeding did produce seasonal snowpack increases of 5–10 percent; as measured by stream runoff data (a conservative surrogate for snowpack increases). Thus, orographic systems, especially winter orographic systems, would help maximize S. 517 derived program success. Garstang's report apparently was unclear on this fact.

The implementation plan does not include less developed technologies (e.g., extraterrestrial mirrors; ionization, chaos theory-related approaches; sonic initiation of precipitation, making a hurricane disappear from conventional radar), or technologies that are already known to be too costly for the benefits they provide if any (e.g., using vertical pointing jet engines, or mono-layer films to suppress moisture flow into hurricanes), based on insufficient scientific and engineering test results, which pose a significant risk to programmatic success. *The plan does not support funding for Federal Operational cloud seeding, except for small tests/experiments of new technologies.*

In closing, failure to send S. 517 to appropriate committee hearings with the companion Udall Bill (H.R. 2995), translates into desertification, more destructive weather, and even jeopardizes our standing as the premier scientists, engineers and practitioners in this area. We have an implementation plan for the program under this bill. We have the best technology, the brightest personnel to successfully carry out the implementation plan. The 60 years scientific and engineering basis helps assure success. Passing S. 517 now, helps avert adverse efects of desertification, Katrina-like hurricane destruction, and air pollution effect on the rain process, for example. Thus, this tax payer fully supports passage of Senate bill S. 517 with a sufficient budget and duration.

Senator DEMINT. Thank you, Doctor.

Dr. Garstang?

STATEMENT OF MICHAEL GARSTANG, PH.D., PROFESSOR, UNIVERSITY OF VIRGINIA; CHAIR, COMMITTEE ON CRITICAL ISSUES IN WEATHER MODIFICATION RESEARCH, NATIONAL RESEARCH COUNCIL OF THE NATIONAL ACADEMIES

Dr. GARSTANG. Thank you, Chairman Hutchison and Senator DeMint.

My name is Michael Garstang. I am a Distinguished Emeritus Research Professor in the Department of Environmental Sciences at the University of Virginia. I'm a fellow of the American Meteorological Society. And I was also Chair of the 2003 National Research Council's Committee on Critical Issues in Weather Modification Research. The National Research Council is the operating arm of the National Academies, chartered by Congress in 1863 to advise the Government on matters of science and technology.

This afternoon, I will give you a brief summary of the status of weather modification research as described in our report. You'll be provided with the executive summary of that report.

Efforts to minimize harmful weather effects go far back in time. The first serious scientific efforts in the United States began in the 1950s. This effort was not sustained. During the past 30 years, there has been a progressive decline in weather modification research. Research support related to weather modification in the United States has dropped to less than a half a million dollars per year in the year 1999, from a high of $20 million in the late 1970s.

There have been, concurrently, significant advances in technology over the past 30 years. This has greatly improved our ability to observe, understand, and predict the weather. These advances, however, have not been either collectively or persistently applied to the problem of weather modification.

This decline in research must—may be the result of a combination of factors, including early over-optimistic claims, unrealistic expectations, and a failure to provide scientifically demonstrable successes. But, despite these limitations, and because of the considerable pressures that my colleagues have already indicated resulting from drought, hail, floods, and storm damage, private and State agencies spend significant resources to attempt to modify the weather.

In 2001, there were 66 operational weather modification programs in ten States in the Union, and much more activity overseas. How do we overcome this disparity between our willingness to attempt to modify the weather and our reluctance to fund research to understand such activities?

The NRC's committee concluded that, first, with few exceptions, there is still no convincing scientific proof of the efficacy of intentional weather modification. In some instances, encouraging results have been observed, but this evidence has not been subjected to adequate testing.

Second, that despite this lack of proof, scientific understanding has progressed on many fronts. For instance, there has been substantial improvements in ice-nucleating capabilities of new seeding materials. Also, new technologies such as satellite imagery are giving us tools to better understand microphysical processes that lead to precipitation. Dr. Golden referred to this. These advantages will help us focus and optimize weather modification research.

Third, that if progress in establishing our capability to modify the weather is to be made, the focus must be on key uncertainties that hamper progress. For example, there are critical gaps in our understanding of the complex chain of physical processes that lead to rain, snow, and hail.

The NRC committee's primary recommendation is the establishment of a coordinated national program of weather modification research designed to reduce these and other key uncertainties. The program should consist of a sustained research effort that uses a balanced approach of modeling, laboratory studies, and field measurements. Instead of focusing on near-term operational applications of weather modification, the program should address fundamental questions. It should take full advantage of recent related research and advances in observational, computational, and statistical technologies.

Our Committee—in our—in the Committee's opinion, it is premature to initiate large operational weather modification programs. Instead, great opportunity exists to coordinate research efforts to address fundamental questions that will lead to credible scientific results. Focused investigation of atmospheric processes plus coupled technological applications will advance understanding and bring many unexpected benefits. This research will place us in a position to determine whether, how, and to what extent weather systems can be modified.

In conclusion, the NRC committee emphasizes that weather modification should be viewed as a fundamental and legitimate part of the atmospheric and environmental science. Growing demand for fresh water, increasing levels of damage and loss of life resulting from severe weather, the undertaking of operational ac-

tivities without the guidance of a sound scientific foundation, and the reality of inadvertent atmospheric changes, the science community now has the opportunity, the challenge, and the responsibility to assess the potential efficacy and value of intentional weather modification.

Thank you for the opportunity to testify. I will be happy to answer questions.

[The prepared statement of Dr. Garstang follows:]

PREPARED STATEMENT OF MICHAEL GARSTANG, PH.D., PROFESSOR, UNIVERSITY OF VIRGINIA; CHAIR, COMMITTEE ON CRITICAL ISSUES IN WEATHER MODIFICATION RESEARCH, NATIONAL RESEARCH COUNCIL OF THE NATIONAL ACADEMIES

Good afternoon Chairmen Hutchison and DeMint, Ranking Members Bill Nelson and Ben Nelson, and Members of the Subcommittees. My name is Michael Garstang, and I am a Distinguished Emeritus Research Professor in the Department of Environmental Sciences at the University of Virginia. I'm a fellow of the American Meteorological Society (AMS) and have served on numerous AMS committees. I was also the chair of the 2003 National Research Council's (NRC) Committee on Critical Issues in Weather Modification Research. The National Research Council is the operating arm of the National Academies, chartered by Congress in 1863 to advise the government on matters of science and technology.

This afternoon I will give you a brief summary of the status of weather modification research, as described in our NRC report, the major uncertainties that exist, and convey the Committee's conclusions and recommendations. We will also provide an Executive Summary of the report which lists the key findings and recommendations in greater detail.

Efforts to minimize harmful weather impacts go back far in time. In the last 30 years, significant evidence has accumulated that human activities unintentionally affect the weather on scales ranging from local to global. Many of the same fundamental principles underlie both intentional and unintentional weather modification. Yet during this 30-year time period, there has been a progressive decline in weather modification research. Research support related to weather modification in the United States had dropped to less than $0.5M per year in 1999 from a high of $20M in the late 1970s. During the same period, there have been significant advances in technology. This has greatly improved our ability to observe, understand, and predict the weather. These advances, however, have not been either collectively or persistently applied to the problem of weather modification.

This decline in research is likely the result of a combination of factors, including early overly-optimistic claims, unrealistic expectations, and failure to provide scientifically demonstrable successes. But despite these limitations, and because of considerable pressures resulting from drought, hail, floods, and storm damage, private and state agencies actually spend significant resources on attempts to modify the weather. In 2001, there were 66 operational weather modification programs in 10 states and much more activity overseas.

How do we overcome this disparity between our willingness to attempt to modify weather and our reluctance to fund research to understand such activities? The 2003 National Academies committee that I chaired was charged to provide an updated assessment of the current state and the future of weather modification research, from new technologies to advances in numerical modeling and operations. A summary of our report is included in my written testimony. In my comments, I want to focus on our conclusions and recommendations.

First, with a few exceptions, the Committee concluded that there still is no convincing scientific proof of the efficacy of intentional weather modification efforts. In some instances encouraging results have been observed, but this evidence has not been subjected to adequate testing.

Second, despite this lack of proof, the Committee concluded that scientific understanding has progressed on many fronts. For instance, there have been substantial improvements in the ice-nucleating capabilities of new seeding materials. Also, new technologies such as satellite imagery are giving us tools to better understand the microphysical processes that lead to precipitation, and these advances, in time can help focus and optimize weather modification research.

Third, the Committee stated that if progress in establishing our capability to modify the weather is to be made, intellectual and technical resources must be brought to bear on the key uncertainties that hamper progress. For example, there are crit-

ical gaps in our understanding of the complex chain of physical processes that lead to rain, snow, and hail.

Finally, and most importantly, the Committee called for the establishment of a coordinated national program of weather modification research designed to reduce these and other key uncertainties. The program should consist of a sustained research effort that uses a balanced approach of modeling, laboratory studies, and field measurements. Instead of focusing on near-term operational applications of weather modification, the program should address fundamental research questions. It should take full advantage of recent related research and advances in observational, computational, and statistical technologies, by:

- Capitalizing on new remote and *in situ* observational tools to carry out exploratory and confirmatory experiments in a variety of cloud and storm systems;
- Improving model treatment of cloud and precipitation physics;
- Improving the use of current computational and data assimilation methods; and
- Capitalizing on existing field facilities and developing partnerships among research groups and select operational programs.

In the Committee's opinion, it is premature to initiate large-scale operational weather modification programs. However, a great opportunity exists to coordinate research efforts to address the fundamental questions that will lead to credible scientific results. Focused investigation of atmospheric processes, coupled with technological applications, will advance understanding and bring many unexpected benefits and results. In time, this research will place us in a position to determine whether, how, and to what extent weather and weather systems can be modified.

Closing Thoughts

The NRC Committee emphasizes that weather modification should be viewed as a fundamental and legitimate element of atmospheric and environmental science. Owing to the growing demand for fresh water, the increasing levels of damage and loss of life resulting from severe weather, the undertaking of operational activities without the guidance of a careful scientific foundation, and the reality of inadvertent atmospheric changes, the scientific community now has the opportunity, challenge, and responsibility to assess the potential efficacy and value of intentional weather modification technologies.

Thank you for the opportunity to testify. I would be happy to answer any questions the Subcommittees might have.

EXECUTIVE SUMMARY

The weather on planet Earth is a vital and sometimes fatal force in human affairs. Efforts to control or reduce the harmful impacts of weather go back far in time. In recent decades our ability to observe and predict various types of meteorological systems has increased tremendously. Yet during this same period there has been a progressive decline in weather modification research. Extravagant claims, unrealistic expectations, and failure to provide scientifically demonstrable success are among the factors responsible for this decline. Significantly, every assessment of weather modification dating from the first National Academies' report in 1964 has found that scientific proof of the effectiveness of cloud seeding was lacking (with a few notable exceptions, such as the dispersion of cold fog). Each assessment also has called for a dedicated research effort directed at removing or reducing basic scientific uncertainties before proceeding with the application of weather modification methods. Yet, this type of intensive, committed effort has not been carried out.

In this, the latest National Academies' assessment of weather modification, the Committee was charged to provide an updated assessment of the ability of current and proposed weather modification capabilities to provide beneficial impacts on water resource management and weather hazard mitigation. It was asked to examine new technologies, such as ground-based, in situ, and satellite detection systems, and fast reacting seeding materials and dispensing methods. The Committee also was asked to review advances in numerical modeling on the cloud and mesoscale and consider how improvements in computer capabilities might be applied to weather modification. This study was not designed to address policy implications of weather modification; rather it focused on the research and operational issues. Specifically, the Committee was asked to:

- review the current state of the sciences of weather modification and the role of weather prediction as it applies to weather modification, paying particular attention to the technological and methodological developments of the last decade;

- identify the critical uncertainties limiting advances in weather modification science and operation;
- identify future directions in weather modification research and operations for improving the management of water resources and the reduction in severe weather hazards; and
- suggest actions to identify the potential impacts of localized weather modification on large-scale weather and climate patterns.

Issues and Trends in Weather Modification

Motivation

Increasing demands for water make the potential for enhancing the sources, storage, and recycling of freshwater a legitimate area of study. Destruction and loss of life due to severe weather, which is increasing with population growth and changing demographics, require that we examine ways to reduce these impacts. In addition, there is ample evidence that human activities, such as the emission of industrial air pollution, can alter atmospheric processes on scales ranging from local precipitation patterns to global climate. These inadvertent impacts on weather and climate require a concerted research effort, yet the scientific community has largely failed to take advantage of the fact that many of the scientific underpinnings of intentional and unintentional weather modification are the same.

Current Operational and Research Efforts

Operational weather modification programs, which primarily involve cloud-seeding activities aimed at enhancing precipitation or mitigating hail fall, exist in more than 24 countries, and there were at least 66 operational programs being conducted in 10 states across the United States in 2001. No Federal funding currently is supporting any of these operational activities in the United States. Despite the large number of operational activities, less than a handful of weather modification research programs are being conducted worldwide. After reaching a peak of $20 million per year in the late 1970s, support for weather modification research in the United States has dropped to less than $500,000 per year.

The Paradox

Clearly, there is a paradox in these divergent trends: The Federal Government is not willing to fund research to understand the efficacy of weather modification technologies, but others are willing to spend funds to apply these unproven techniques. Central to this paradox is the failure of past cloud-seeding experiments to provide an adequate verification of attempts at modifying the weather. A catch-22 ensues in which the inability to provide acceptable proof damages the credibility of the entire field, resulting in diminished scientific effort to address problems whose solutions would almost certainly lead to better evaluations.

Limitations and Problems

The dilemma in weather modification thus remains. We know that human activities can affect the weather, and we know that seeding will cause some changes to a cloud. However, we still are unable to translate these induced changes into verifiable changes in rainfall, hail fall, and snowfall on the ground, or to employ methods that produce credible, repeatable changes in precipitation. Among the factors that have contributed to an almost uniform failure to verify seeding effects are such uncertainties as the natural variability of precipitation, the inability to measure these variables with the required accuracy or resolution, the detection of a small induced effect under these conditions, and the need to randomize and replicate experiments.

Conclusions

The Committee concludes that there still is no convincing scientific proof of the efficacy of intentional weather modification efforts. In some instances there are strong indications of induced changes, but this evidence has not been subjected to tests of significance and reproducibility. This does not challenge the scientific basis of weather modification concepts. Rather it is the absence of adequate understanding of critical atmospheric processes that, in turn, lead to a failure in producing predictable, detectable, and verifiable results. Questions such as the transferability of seeding techniques or whether seeding in one location can reduce precipitation in other areas can only be addressed through sustained research of the underlying science combined with carefully crafted hypotheses and physical and statistical experiments.

Despite the lack of scientific proof, the Committee concludes that scientific understanding has progressed on many fronts since the last National Academies' report

and that there have been many promising developments and advances. For instance, there have been substantial improvements in the ice-nucleating capabilities of new seeding materials. Recent experiments using hygroscopic seeding particles in water and ice (mixed-phase) clouds have shown encouraging results, with precipitation increases attributed to increasing the lifetime of the rain-producing systems. There are strong suggestions of positive seeding effects in winter orographic glaciogenic systems (i.e., cloud systems occurring over mountainous terrain). Satellite imagery has underlined the role of high concentrations of aerosols in influencing clouds, rain, and lightning, thus drawing the issues of intentional and inadvertent weather modification closer together. This and other recent work has highlighted critical questions about the microphysical processes leading to precipitation, the transport and dispersion of seeding material in the cloud volume, the effects of seeding on the dynamical growth of clouds, and the logistics of translating storm-scale effects into an area-wide precipitation effect. By isolating these critical questions, which currently hamper progress in weather modification, future research efforts can be focused and optimized.

Additional advances in observational, computational, and statistical technologies have been made over the past two to three decades that could be applied to weather modification. These include, respectively, the capabilities to (1) detect and quantify relevant variables on temporal and spatial scales not previously possible; (2) acquire, store, and process vast quantities of data; and (3) account for sources of uncertainty and incorporate complex spatial and temporal relationships. Computer power has enabled the development of models that range in scale from a single cloud to the global atmosphere. Numerical modeling simulations—validated by observations whenever possible—are useful for testing intentional weather modification and corresponding larger-scale effects. Few of these tools, however, have been applied in any collective and concerted fashion to resolve critical uncertainties in weather modification. These numerous methodological advances thus have not resulted in greater scientific understanding of the principles underlying weather modification. This has not been due to flawed science but to the lack of support for this particular field of the science over the past few decades. As a result there still is no conclusive scientific proof of the efficacy of intentional weather modification, although the probabilities for seeding-induced alterations are high in some instances. Despite this lack of scientific proof, operational weather modification programs to increase rain and snowfall and to suppress hail formation continue worldwide based on cost versus probabilistic benefit analyses.

Recommendations

Recommendation: Because weather modification could potentially contribute to alleviating water resource stresses and severe weather hazards, because weather modification is being attempted regardless of scientific proof supporting or refuting its efficacy, because inadvertent atmospheric changes are a reality, and because an entire suite of new tools and techniques now exist that could be applied to this issue, the Committee recommends that there be a renewed commitment to advancing our knowledge of fundamental atmospheric processes that are central to the issues of intentional and inadvertent weather modification. The lessons learned from such research are likely to have implications well beyond issues of weather modification. Sustainable use of atmospheric water resources and mitigation of the risks posed by hazardous weather are important goals that deserve to be addressed through a sustained research effort.

Recommendation: The Committee recommends that a coordinated national program be developed to conduct a sustained research effort in the areas of cloud and precipitation microphysics, cloud dynamics, cloud modeling, and cloud seeding; it should be implemented using a balanced approach of modeling, laboratory studies, and field measurements designed to reduce the key uncertainties listed in Box ES.1. This program should not focus on near-term operational applications of weather modification; rather it should address fundamental research questions from these areas that currently impede progress and understanding of intentional and inadvertent weather modification. Because a comprehensive set of specific research questions cannot possibly be listed here, they should be defined by individual proposals funded by a national program. Nevertheless, examples of such questions may include the following:

- What is the background aerosol concentration in various places, at different times of the year, and during different meteorological conditions? To what extent would weather modification operations be dependent on these background concentrations?

- What is the variability of cloud and cell properties (including structure, intensity, evolution, and lifetime) within larger clusters, and how do clouds and cells interact with larger-scale systems? What are the effects of localized seeding on the larger systems in which the seeded clouds are embedded?
- How accurate are radar reflectivity measurements in measuring the differences between accumulated rainfall in seeded and unseeded clouds? How does seeding affect the drop-size distribution that determines the relationship between the measured radar parameter and actual rainfall at the surface?

BOX ES.1

Summary of Key Uncertainties

The statements in boldface type are considered to have the highest priority.

Cloud/precipitation microphysics issues

- **Background concentration, sizes, and chemical composition of aerosols that participate in cloud processes**
- Nucleation processes as they relate to chemical composition, sizes, and concentrations of hygroscopic aerosol particles
- Ice nucleation (primary and secondary)
- Evolution of the droplet spectra in clouds and processes that contribute to spectra broadening and the onset of coalescence
- Relative importance of drizzle in precipitation processes

Cloud dynamics issues

- **Cloud-to-cloud and mesoscale interactions as they relate to updraft and downdraft structures and cloud evolution and lifetimes**
- Cloud and sub-cloud dynamical interactions as they relate to precipitation amounts and the size spectrum of hydrometeors
- Microphysical, thermodynamical, and dynamical interactions within clouds

Cloud modeling issues

- **Combination of the best cloud models with advanced observing systems in carefully designed field tests and experiments**
- Extension of existing and development of new cloud-resolving models explicitly applied to weather modification
- Application of short-term predictive models including precipitation forecasts and data assimilation and adjoint methodology in treated and untreated situations
- Evaluation of predictive models for severe weather events and establishment of current predictive capabilities including probabilistic forecasts
- Advancement of the capabilities in cloud models to simulate dispersion trajectories of seeding material
- Use of cloud models to examine effects of cloud seeding outside of seeded areas
- Combination of cloud models with statistical analysis to establish seeding effects

Seeding-related issues

- **Targeting of seeding agents, diffusion and transport of seeding material, and spread of seeding effects throughout the cloud volume**
- **Measurement capabilities and limitations of cell-tracking software, radar, and technologies to observe seeding effects**
- Analysis of recent observations with new instruments of high concentrations of ice crystals
- Interactions between different hydrometeors in clouds and how to best model them
- Modeling and prediction of treated and untreated conditions for simulation
- Mechanisms of transferring the storm-scale effect into an area-wide precipitation effect and tracking possible downwind changes at the single cell, cloud cluster, and floating target scales

The tasks involved in weather modification research fall within the mission responsibilities of several government departments and agencies, and careful coordination of these tasks will be required.

Recommendation: The Committee recommends that this coordinated research program include:

- Capitalizing on new remote and in situ observational tools to carry out exploratory and confirmatory experiments in a variety of cloud and storm systems (e.g., Doppler lidars and airborne radars, microwave radiometers, millimeter-wave and polarimetric cloud radars, global positioning system (GPS) and cell-tracking software, the Cloud Particle Imager, the Gerber Particle Volume Monitor, the Cloud Droplet Spectrometer). Initial field studies should concentrate on areas that are amenable to accurate numerical simulation and multiparameter, three-dimensional observations that allow the testing of clearly formulated physical hypotheses. Some especially promising possibilities where substantial further progress may occur (not listed in any priority) include:

  —*Hygroscopic seeding to enhance rainfall*. The small-scale experiments and larger-scale coordinated field efforts proposed by the Mazatlan workshop on hygroscopic seeding (WMO, 2000) could form a starting point for such efforts. A randomized seeding program with concurrent physical measurements (conducted over a period as short as three years) could help scientists to either confirm or discard the statistical results of recent experiments.

  —*Orographic cloud seeding to enhance precipitation*. Such a program could build on existing operational activities in the mountainous western United States. A randomized program that includes strong modeling and observational components, employing advanced computational and observational tools, could substantially enhance our understanding of seeding effects and winter orographic precipitation.

  —*Studies of specific seeding effects*. This may include studies such as those of the initial droplet broadening and subsequent formation of drizzle and rain associated with hygroscopic seeding, or of the role of large (>1 μm) particles (e.g., sea spray) in reducing droplet concentrations in polluted regions where precipitation is suppressed due to excess concentrations of small cloud condensation nuclei (CCN).

- Improving cloud model treatment of cloud and precipitation physics. Special focus is needed on modeling CCN, ice nuclei processes, and the growth, collision, breakup, and coalescence of water drops and ice particles. Such studies must be based on cloud physics laboratory measurements, tested and tuned in model studies, and validated by in situ and ground observations.
- Improving and using current computational and data assimilation capabilities. Advances are needed to allow rapid processing of large quantities of data from new observations and better simulation of moist cloud and precipitation processes. These models could subsequently be used as planning and diagnostic tools in future weather modification studies, and to develop techniques to assist in the evaluation of seeding effects.
- Capitalizing on existing field facilities and developing partnerships among research groups and select operational programs. Research in weather modification should take full advantage of opportunities offered by other field research programs and by operational weather modification activities. Modest additional research efforts directed at the types of research questions mentioned above can be added with minimal interference to existing programs. A particularly promising opportunity for such a partnership is the Department of Energy Atmospheric Radiation Measurement program/Cloud and Radiation Test bed (DOE ARM/CART) site in the southern Great Plains (Oklahoma/Kansas) augmented by the National Aeronautics and Space Administration (NASA) Global Precipitation Mission. This site provides a concentration of the most advanced observing systems and an infrastructural base for sustained basic research. The National Center for Atmospheric Research (NCAR) and the National Oceanic and Atmospheric Administration's Environmental Technology Laboratory (NOAA/ETL) also could serve as important focal points for weather modification research.

In pursuing research related to weather modification explicit, financial and collegial support should be given to young aspiring scientists to enable them to contribute to our fundamental store of knowledge about methods to enhance atmospheric resources and reduce the impacts of hazardous weather. It must be acknowl-

edged that issues related to weather modification go well beyond the limits of physical science. Such issues involve society as a whole, and scientific weather modification research should be accompanied by parallel social, political, economic, environmental, and legal studies.

The Committee emphasizes that weather modification should be viewed as a fundamental and legitimate element of atmospheric and environmental science. Owing to the growing demand for fresh water, the increasing levels of damage and loss of life resulting from severe weather, the undertaking of operational activities without the guidance of a careful scientific foundation, and the reality of inadvertent atmospheric changes, the scientific community now has the opportunity, challenge, and responsibility to assess the potential efficacy and value of intentional weather modification technologies.

Closing Thoughts

The Academy Committee emphasizes that weather modification should be viewed as a fundamental and legitimate element of atmospheric and environmental science. The growing demand for fresh water, the increasing levels of damage and loss of life resulting from severe weather, the undertaking of operational activities without the guidance of a careful scientific foundation, and the reality of inadvertent atmospheric changes gives the scientific community the opportunity, challenge, and the responsibility to determine how and to what extent humans can influence the weather.

Senator DEMINT. Thank you, Doctor.

Chairman Hutchison is here. I believe she would like to make an opening statement.

STATEMENT OF HON. KAY BAILEY HUTCHISON, U.S. SENATOR FROM TEXAS

Senator HUTCHISON [presiding]. Thank you.

Well, I very much appreciate the three of you coming. I'm sorry I'm late, but I do want to talk to you. I've read your testimony, and I've also read the executive summary of the report in which you participated. This was an issue brought to me by a distinguished former State Senator from Texas, John Leedom, who is with us today, and his wife, Betty, I see. But I thought that the points that he made to me were certainly worth pursuing.

And it seems to me, from all of your testimony, that further research is something that the scientific community wants to see happen. And I think, from what Dr. Garstang has just said, that the view of the scientific community and the committee that you are on is that we shouldn't be running out there doing things until we have the research that either proves what the long-term effects are going to be, or not. And I think it's very important that we pursue this research, which is why I've introduced the legislation.

I am very interested in the findings and recommendations of the Committee in which they say that it is recommended that we have a sustained research effort in this area. And I want to pursue this a little further when we get into questions. I know that Senator DeMint has to be on the floor at 3 p.m., so I'm going to defer to him to ask his questions first. But I am going to want to talk to the three of you about how we should pursue this research, which is the purpose of my bill, and to get the best results, and especially to determine, from what was said in the report—that there is a growing demand for fresh water, the increasing levels of damage and loss resulting from severe weather—would indicate that we should be researching what we can do to mitigate damage and also provide a more steady, even, and balanced source of fresh water,

rather than having a Hurricane Katrina while there is a drought in other parts of our country.

So, I will pursue that, but I will yield to Senator DeMint, because he has another—this, I will tell you, just so that you understand—because this is the last week or 10 days of our session, all of us have hearings and conference committees, which is what I had to attend earlier, and why I'm late. We had a conference committee on our transportation bill, and I'm sure you're going to the floor for your bill. So, why don't you go——

Senator DEMINT. OK.

Senator HUTCHISON.—forward, and I will——

Senator DEMINT. Thank you——

Senator HUTCHISON.—follow you.

Senator DEMINT.—Chairman.

Just a quick question, and I will have to leave in a just a moment, but——

This is a fascinating subject for me. The idea that we could actually impact weather is exciting and, I guess, frightening, in some ways. But, Dr. Golden, you mentioned just some successes, the successes of adding to the snowfall in mountains and, again, I guess we can't get into a lot of science today, but I assume if we're able to get additional snow in one area, that some other area is not going to get as much rainfall or moisture-fall. I mean, we're not putting more moisture in the air, we're just collecting it in a different place. Is that the concept?

Dr. GOLDEN. This is one of the very areas that we need to do a lot of additional research under Senator Hutchison's bill. But the work that has been done—and there are—we did some of this on our FACE program in Florida. We looked at what you're talking about is extra-area effects. If you seed in a target area, are you robbing Peter to pay Paul in areas that are downwind? And both in the FACE Project, as well as in other States—in Utah, we looked at possible downwind effects from seeding in the mountains of Utah. Did they see any decreased snowfall in Southwestern Wyoming? The answer is no. Even the most ardent proponents of the mountain seeding will tell you that you're only processing—you're only affecting a very small fraction of the water vapor that passes over the mountains. And so, all of the results in both winter oragraphic mountain seeding, as well as convective storm seeding suggests that either you have no effect downwind or it's a slight increase. But, again, there needs to be additional research. There's nothing that suggests large increases outside your target area. It's either no effect or very weak positive effect.

Senator DEMINT. And you mentioned other countries apparently using this successfully. I mean, are there any studies that the scientific community would recognize that says Australia, or, I think you mentioned, China, have actually been successful in weather modification?

Dr. GOLDEN. Some of them, yes, but it's still—I think what Dr. Garstang says is true, there still needs to be work on evaluation. And while I'm not a strong proponent of using only statistical evaluation, I think, for example, there are—some of the new computer models and tracers—we now have come a long way in just the last 10 years; and this is an effort that we pioneered in this country.

There are now tracer techniques that you can use right when you seed to tell you not only how much increase in snow is due to the seeding, but how much of the seeding material actually made it into the snow that fell. And so, this has just been developed over the last 10 years, and they're just starting to apply this technology in the Australia program. So——

Senator DEMINT. Well, thank——

Senator HUTCHISON. Could I ask a question just on that——

Senator DEMINT. Sure.

Senator HUTCHISON.—same subject, while you're here?

There are ten States and probably 66 operational modification programs just ongoing now by States and local water agencies. Is there any place that those projects that are ongoing, operations that are ongoing, where data is collected at a central point so that we do see the effects of those particular operations as they are supposed to be working?

Dr. GOLDEN. No. You raise a very good point. I mean, that's what we're all about today, is—I talked to one of the biggest operators that supports many of these programs, both in the U.S.—many of the operational weather modification programs—and they told me that—he estimates that there is now an expenditure per year, a combined expenditure, just in our country, of $25 to $30 million per year on operations. But since the demise of my AMP program, there is no central focus. And, frankly, most of the operational groups that support the seeding activity feel that most of their funding has to go to the seeding effort, to the operations. So, they look to the Government. They look to the Federal Government to play the major role here.

To be honest with you, some of them, recognizing the value of research to helping them evaluate what they do, are supporting small research efforts. The newest entry into this, by the way, is the State of Wyoming. They're about to start a new $8 million program of snowpack seeding enhancement.

Senator HUTCHISON. At the very least, we ought to be——

Senator DEMINT. Yes.

Senator HUTCHISON.—gathering the data.

Senator DEMINT. So, we're spending $25 million a year, but we really don't have any quantitative data that suggests that it works, just more of an—empirical evidence that people believe there is some impact, right?

Dr. GOLDEN. They do their own evaluation. No, I don't mean to say—they are not—not much of that money is going to support any of the research that Dr. Garstang recommended in his report. Most of that is for their operations and some evaluation.

Senator HUTCHISON. But nothing is gathered nationally——

Dr. GOLDEN. Right.

Senator HUTCHISON.—to see what the effects are.

Senator DEMINT. You're going to have to excuse me.

Senator HUTCHISON. OK, thank you.

I wanted to ask you, because we've been through some particularly bad weather situations this year, is there any thought in the scientific community that you could, by, say, seeding, maybe, a hurricane in the early stages, that you could lessen its effect, make it start dropping earlier, and lessen its effect when it hits land? Is

there any potential for that kind of modification? We've been talking about modification, obviously, over land, where you're trying to get rain for crops. But we also are looking at ways to maybe even out the kind of weather and rainfall that we would have. Is there any hope that we could eventually use some kind of scientific means like this to take out the violence of a storm?

Dr. GARSTANG. I'll pick that one up, Senator Hutchison.

Yes, as Dr. Golden said, there was a program, STORMFURY, that did, indeed, attempt to—and they used the word "moderate" a hurricane, change its wind speeds. And although it's controversial now, there was a conclusion that they had, indeed, got evidence for a reduction of 15 percent in the wind speeds. Now, if you take a hurricane wind from 100 miles an hour down to 85 miles an hour, the damage is the square of the wind velocity, so you mitigate damage considerably. However, as I said, there's question about that.

There are no current methodologies that could be employed to reduce or to deflect a hurricane. However, there are very promising computer models that are beginning to suggest how we might approach this. And, interestingly enough from what Dr. Golden said, one of the most advanced pieces of work is being done by the European community's National Center for Meteorology or long-range/medium-range forecasting. And it's using our ideas. But there are efforts in this country where the model suggests that very small effects might have quite drastic consequences. And this is a characteristic of the atmosphere.

I'm sure you know that the whole theory of chaos came from a meteorologist, Dr. Ed Lorenz, from MIT, where he was trying to determine what, in all these small effects—and to use the kind of analogy that he used, the flapping of a butterfly's wings in Brazil creates a tornado in Kansas. In other words, these very tiny effects can have, ultimately, very large consequences.

Models now are being used to find these. Are they there, and can we find them? And Dr. Ross Hoffman's work suggests that, yes, they are. It's not clear how you would necessarily bring that about, but if we don't pursue this work, we will never know the answer.

So, the answer is: not right now, but yes in the future.

Senator HUTCHISON. Thank you.

Dr. DeFelice?

Dr. DEFELICE. Yes, I'd like to just add to this. I think the—excuse me, technical difficulties—I think under your bill, once it's passed, I would recommend to the board an implementation plan for the research that would be conducted under it, and part of that plan would involve hurricane modification and some of the issues that my distinguished colleagues have mentioned. But I would just want to emphasize the need to do modeling studies to test all possible seeding scenarios relative to the result of those inputs. Get the best models that we can on hurricanes, because there are really—there's some really good ones out there, even in the United States. And then have some of our computer scientists add a computer program—or a subroutine that would act like we were seeding them, but not do any seeding.

Under our plan, the implementation plan for this bill, there would be no way that the Government would be doing any oper-

ational cloud-seeding or anything like that. They would—hurricane modification and all that research would have to be done by models. And once the modeling studies were complete, then one might form a hypothesis which might be testable out in the field. But we would know what would happen or think we know what would happen, based on the models. I just wanted to emphasize the use of models in any severe-storm type of modification research that happens under this bill. At least that would be my view and hope.

Senator HUTCHISON. If you were going to do an implementation plan—say, we pass the bill, we have appointments to the board, and you would want a representative board from the different areas of weather expertise, but what areas do you think would be the most productive in which to do research? Obviously, cloud-seeding for fresh water. And hurricane or violent weather modification would be two. What else could we gain from this kind of effort?

Dr. DEFELICE. I'll start, and then I'm sure there'll be plenty to add to it.

I would think that we might consider looking into clearing out fog in the vicinity of airports, and perhaps other areas, particularly in the Northeast, which might benefit from increased sunlight particularly during the winter. So, these would be cold clouds. Another area would be hygroscopic seeding. And there's a lot that's not known about that. There's a lot of promising results.

Senator HUTCHISON. "Hygroscopic," being?

Dr. DEFELICE. Putting small salt nuclei into the proper part of the cloud so that those nuclei would help enhance the interaction between the droplets in the cloud, so that would then, in turn, produce more precipitation.

Senator HUTCHISON. Is that different from other types of cloud-seeding, or are there different forms?

Dr. DEFELICE. It's just that—that is different in the sense that it's just a different way to trigger the precipitation process in the cloud. You can use agents that would grow ice crystals in the cloud. But those clouds would have to be cold enough for the ice to exist, if it was to form.

Senator HUTCHISON. OK.

Dr. DEFELICE. But those would be the primary areas.

Senator HUTCHISON. Any others?

Dr. GOLDEN. I want to emphasize—and I wish Senator DeMint were here—that one of the terrible things that happened when we cut STORMFURY in the early 1980s was that, beginning at that point, the research funding for hurricane research in NOAA steadily declined. And it's declined ever since. The other thing that happened is that most of our research on cloud physics evaporated. People left the agency, people changed their careers. In fact, there are almost no cloud physicists left—cloud physicists in NOAA have become an endangered species.

Why is that important? It means that if you don't understand the cloud physics, as Dr. Garstang emphasized, you have no hope of understanding how you might beneficially modify clouds to produce increased rainfall. And that feeds back into being able to predict heavy rain and heavy snow. In other words, this is one of the top priorities for my colleagues in the National Weather Service. I mean, we all get frustrated that our skill scores, our forecast accu-

racies for heavy rain or heavy snow aren't what they need to be. And so, this is all linked together, so that there is no doubt in my mind that any investment by this bill in weather modification research will yield big payoffs in the prediction arena. And, as I said in my testimony, ultimately we're never going to be able to convince ourselves or anyone else that we're successful in weather modification unless we can do a good job of predicting the unmodified natural event. That's the—that's one of the most fundamental questions.

Dr. GARSTANG. I certainly agree with all of those sentiments. But I'd like to emphasize that if the bill could bring cohesive and sustained effort directed at solving the outstanding problems that we know are roadblocks to our progress, if you can remove these roadblocks, you can progress. And if you simultaneously, with this coherent program, brought to bear on it all of the technological advances that have occurred in the last 30 years, there would be immediate and tremendous advances. Dr. Golden has referred to a couple.

For example, in the successful, I think, attempts at increasing snowpack on the Sierras and western slopes of the Rockies, we didn't know where the seeding material was going. We now can determine precisely where it's going. And often it didn't go where we thought it was going, didn't go where it would do any good. We also can precisely describe the flow fields through the cloud. We couldn't do that 10 years ago.

These techniques have not been coherently brought to bear on weather modification. As soon as we do that, we will have immediate results.

Let me give you an analogy. Let's assume that all of cardiac investigations were prevented from using the technological advances that have occurred in heart research over the last 20 years. Where would we be in preventing heart disease today? We would be way behind where we are.

We have not brought these same kind of sophisticated techniques, which are in place, to bear on the problem. And if you could create that situation where that was possible, you would get immediate results.

Senator HUTCHISON. Have you looked at my bill? I would like to ask each of you. And do you have any suggestions on any ways to improve it?

Basically, what I'm trying to do is establish this research and a board that would be made up of experts from these various areas with various expertise that would be advisory to the Department of Commerce and NOAA. And my question is, Is there something that you would suggest that would make it any more able to achieve the goal of more emphasis on research, an implementation of the research, and an advisory board made up of experts that would really focus the Department on the areas that should be looked at that we've discussed?

Dr. DEFELICE. I think, as—let me just check—thank you. As I looked through the bill, I think one rule of thumb that I'd like to see—and I believe I've seen this—was to have a multidisciplinary approach to the research agenda, and have the board basically get together with these multidisciplinary components of the field and

discuss the priorities. Now, we come up with priorities, and this is great. And, from what I heard they make sense. But there might not be enough money to carry out all of those particular items. So, I think we need to make sure that we have representatives from all components of the system that we're trying to research, including the general public. So, if the general public is going to be involved, then we might have to have an outreach component, which I strongly urge be in there. I think it is. And we would want representatives from the scientists—science community, maybe some sociologists, economics-type people, commerce, and, so on. But the point is, we want people that are affected by the system, and we need those people to represent each component of that system, so that when we do develop the priorities, everybody will be represented in that process, and will be part of it, and will—should stay with that process from beginning to end.

Senator HUTCHISON. Well, I'd—we certainly——

Dr. DEFELICE.—that's great.

Senator HUTCHISON.—do have a multidisciplinary concept, and if there are any other disciplines that should be added, I would like for you to write me a letter about that later.

Yes?

Dr. GOLDEN. No, I don't want to tinker with your bill. I think that the board is well represented. Is NSF—do they have a representation on the board?

Senator HUTCHISON. It is the—one representative of the National Center for Atmospheric Research of the National Science Foundation.

Dr. GOLDEN. OK. Because they, in the past—this is no longer the case, but in the past, I know that during my AMP Program, we did—some of the States actually got—funded proposals through NSF, and then NSF has also stopped supporting weather modification research. But, I mean, your bill—I think it's fine. I think it says that the board can appoint extra staff, and it can appoint subcommittees. And, no, I wouldn't want to second-guess that. I think once they're assembled, then they can start tackling this issue of national priorities, and I think they'll come to the AMS, they'll come to the American Society of Civil Engineers, they'll come, hopefully, to the Weather Modification Association, and—I mean, these are the venues where the national priorities could be set. I have no problem with that.

Senator HUTCHISON. Dr. Garstang?

Dr. GARSTANG. I have only had the benefit to discuss your bill. I have not read it. We hadn't—it wasn't in time when I got notified to appear here. But I would be glad to look at it carefully, because I gather, from both yourself and from discussions, that you've incorporated a lot of ideas, results from the NRC report. And I would be glad to send these to you—to your staff in writing right away.

Senator HUTCHISON. I would really be pleased if you would, because I think we all are on the same wavelength regarding the need to have an emphasis here, trying to implement that through an advisory board. I think the advisory board—we tried to make it representative of the different areas of expertise, and—so, I'd like to move the bill, so I'd like to have all of your comments and look forward to perhaps being able to do this in——

OK, I'm told that Senator Ben Nelson had a witness recommendation who was unable to attend the hearing and has submitted a statement to be included in the record, Commander Donald Wilhite, Director of the National Drought Mitigation Center at the University of Nebraska. *

Senator HUTCHISON. OK. Well, I have no further questions. Is there anything further that any of you would like to add for the record?

[No response.]

Senator HUTCHISON. If not, we will give you a copy of the bill, Dr. Garstang. And I hope that we can all come together. And I hope Senator DeMint will work with us, as well, to try to move this forward.

Thank you very much for your time, and I learned a lot, and I think we can make some great headway in this area with your expertise.

Thank you.

[Whereupon, at 3:25 p.m., the hearing was adjourned.]

*The information referred to has been printed in the Appendix.

A P P E N D I X

PREPARED STATEMENT OF HON. E. BENJAMIN NELSON,
U.S. SENATOR FROM NEBRASKA

Due to the short notice of the scheduling of the Joint Subcommittee hearing on S. 517, "The Weather Modification Research and Technology Transfer Authorization Act of 2005," I am unable to attend the hearing today. This is an important issue and I regret not being able to reschedule prior commitments in order to be there.

However, I did want to take the opportunity, as we discuss weather modification, to highlight an area of research that is happening at the University of Nebraska related to drought mitigation. While the focus of this hearing is weather modification, I believe it is relevant to address another aspect important to this area of research, which is adequate monitoring of weather patterns so that we may appropriately respond to and mitigate the effects of adverse weather.

The National Drought Mitigation Center (NDMC), located at the University of Nebraska-Lincoln, was established in 1995 and performs a number of activities of importance to Nebraska, the region, and the Nation. Its functions include maintaining a web-based information clearinghouse, drought monitoring, the preparation of the weekly U.S. Drought Monitor (which covers all 50 states), the development of drought policy and planning techniques, collaborative research on improved decision tools for agricultural producers and natural resource managers, and outreach and training workshops for Federal, State, and foreign governments and organizations.

The NDMC has worked with most states in the development of drought mitigation and response plans aimed at reducing vulnerability to episodes of severe drought. The NDMC has worked closely with the Western Governors' Association and NOAA in formulating the proposal for a National Integrated Drought Information System. This system is currently being implemented by NOAA with the assistance of the NDMC.

With this statement, I am submitting a statement from Dr. Donald Wilhite, Director of the NDMC, which details more fully the work they are doing at the University of Nebraska. I believe the research that is being conducted there is critical to our ability to respond to the devastating effects of drought.

This research is especially relevant to Nebraska and other Plains states right now, which have been experiencing drought conditions for several years; but the research done by the NDMC has a national benefit. Droughts have plagued all regions of the country over the past 10 years and many parts of the West have been in drought for 5 to 7 years. They are often slow in developing, but the costs and indirect effects have a substantial impact on water supplies, agriculture, energy production, natural resources, recreation and tourism, transportation, development, and the environment.

The effect of drought in recent years in my state has been devastating. Its impact has been felt throughout the economy of Nebraska. While drought typically does not produce dramatic news footage like a hurricane or tornado will, it is nonetheless, a disaster.

I believe it is crucial to encourage more investment in research in programs such as the NDMC. The research done upfront in monitoring drought trends will help our capabilities to mitigate and respond to its effects in a much more effective manner. I am hopeful that we can hold a hearing on drought in the Disaster Prevention and Prediction Subcommittee next year. This is an important issue that I believe warrants more discussion.

PREPARED STATEMENT OF DR. DONALD WILHITE, DIRECTOR, NATIONAL DROUGHT MITIGATION CENTER, UNIVERSITY OF NEBRASKA-LINCOLN

I appreciate the opportunity to submit this statement on behalf of the National Drought Mitigation Center (NDMC), which is located at the University of Nebraska in Lincoln. Climate variability is an important issue that affects everyone across the

United States. This is true whether it is related to heating bills for the upcoming winter; to El Niño or La Niña events that might cause flooding or drought; or the frequency of natural hazards striking our Nation, like the numerous hurricanes during the past two years. The truth is that drought is one of the costliest hazards to affect the country: FEMA has estimated that the annual losses due to drought are approximately $8 billion, which is a higher estimate than for any other natural hazard. Hurricanes Katrina, Rita, and Wilma may change that placement slightly, but drought remains a serious threat across the United States. The impacts resulting from drought are complex, and as our vulnerability to droughts changes with the shifting pressures on the Nation's finite water resources, impacts due to drought may increase in the future.

I would like to emphasize that drought is a normal part of the climate across the United States. At any given time, approximately 14 percent of the Nation is in severe drought or worse. It is also important to note that multiple-year events (like the 1930s and 1950s, and the 1960s along the East Coast) are not unusual events in the paleo-climate record. For this reason, we need to be prepared for droughts, and focus our attention on mitigation and planning strategies that would reduce drought impacts before droughts strike.

The National Drought Mitigation Center (NDMC) was formed in 1995. At that time, there was no national initiative or program that focused on drought monitoring, mitigation, and preparedness and the Nation was just coming out of a period of serious drought lasting from 1988 to 1994. I have been involved in drought-related research and outreach since 1980, and the formation of the NDMC developed out of a national conference on drought that I organized in 1994. During the first year, our funding came from both NOAA and USDA. Since then, the NDMC's base operating budget is provided through USDA and supplemented by numerous grants from NOAA, NSF, NASA, USGS, BoR, and other USDA agencies.

The NDMC's program is directed at lessening societal vulnerability to drought through a risk-based management approach. The NDMC's activities include promoting and conducting research and outreach activities on drought monitoring, mitigation, and preparedness technologies; improving coordination of drought-related activities and actions within and between levels of government; and assisting in the development, dissemination, and implementation of appropriate mitigation and preparedness technologies in the public and private sectors. Emphasis is placed on research and outreach projects and mitigation/management strategies and programs that stress risk management measures rather than reactive, crisis management actions.

After the NDMC formed, a severe drought struck the Southern Plains and Southwestern United States in 1995–96. Beginning in 1999, the Nation has experienced another series of drought events. These droughts peaked in 2000 and 2002, when close to 40 percent of the Nation was considered to be in severe drought or worse. At the end of July 2002, all 50 states were experiencing some level of dryness or drought, according to the U.S. Drought Monitor. For states in the West (Montana, Wyoming, Nebraska, New Mexico, and Colorado), the drought became a multiple-year event that continues in some of these locations. For states in the Southeast (Georgia and South Carolina, for example), an unprecedented five-year drought took place between 1998 and 2002.

Even during 2005, when the percent area of the country experiencing serious drought fell below that of previous years, an extreme drought spread over parts of Illinois, Iowa, Missouri, Arkansas, and Texas. For some locations, the summer was one of the driest ever. At a few other locations, 2005 is on pace to be the driest year on record, surpassing even the dryness experienced during the famous drought years of the 1930s and 1950s. The area in drought in 2005 included a portion of the Nation's Corn Belt. Estimates of crop losses for Illinois originally totaled $1.3 billion, but recent estimates have improved that number to approximately $0.7 billion, mainly in the northern and central parts of the state. These drought losses could have been much worse without the well-timed moisture remnants moving across the area as a result of several of the hurricanes that struck the Gulf Coast in 2005. The last big drought to hit the Corn Belt hard was in 1988, with estimated crop production-related losses of approximately $15 billion. We narrowly dodged a huge bullet in 2005.

Through these recent droughts, the NDMC has continued to work across the country on its mission. The NDMC maintains its involvement in drought monitoring through the U.S. Drought Monitor map, which is a weekly assessment of the current drought conditions. Two of the NDMC staff, Mark Svoboda and Michael Hayes, serve as authors for this product, along with partners at NOAA and USDA. The NDMC also participates in the monthly North American Drought Monitor, which includes collaboration with Canadian and Mexican scientists. Several countries and

regions around the world have expressed interest in adopting the Drought Monitor format to assess drought conditions. The NDMC has been involved in a NATO project with the Czech Republic to investigate drought monitoring opportunities in Central Europe. In November 2005, the NDMC, NOAA, and USDA will be participating in a bilateral workshop with the Chinese Meteorological Agency on drought monitoring strategies for China.

The NDMC is continuing to conduct research in the broadly defined areas of drought monitoring, mitigation, and planning. We continue to work with NOAA and the Western Governors' Association on the implementation of the National Integrated Drought Information System (NIDIS). The NDMC recently launched a new web-based product directed at development of a web-based drought impacts tool to help NOAA, USDA, and other agencies determine the impacts associated with drought in a timely manner. The NDMC has a proposal pending with NOAA to further support this activity.

In terms of outreach, education, and training, the NDMC continues to maintain and improve its website (drought.unl.edu) and the U.S. Drought Monitor website. These two sites resulted in more than 12 million hits in 2005. We organized and conducted three drought workshops during 2005 and participated in many other workshops and conferences throughout the United States and internationally. The Center continues to assist other states and local governments in the development or revision of drought plans. Thirty-eight states now have drought response or mitigation plans in place, largely through the efforts of the NDMC.

In summary, the NDMC strongly supports more research and development to investigate issues of climate variability, natural hazards, and drought. Our experience with drought is that, in the long run, by making a wise initial investment, the Nation will save money by improving our capability for drought monitoring, mitigation, and response. Initial investments like these will reduce the adverse affects of future climate events on our Nation.

EXECUTIVE OFFICE OF THE PRESIDENT, OFFICE OF SCIENCE AND TECHNOLOGY POLICY

Washington, DC, December 13, 2005

Hon. KAY BAILEY HUTCHISON,
Chairman,
Senate Subcommittee on Science and Space,
Commerce, Science, and Transportation Committee,
Washington, DC.

Dear Senator Hutchison:

This letter is in response to S. 517, "the Weather Modification Research and Development Policy Authorization Act of 2005," reported out by the Senate Committee on Commerce, Science and Transportation on November 17, 2005 (Senate Report No. 109–202). While the Administration recognizes the Committee's interest in weather modification research and development, there is a host of issues—including liability, foreign policy, and national security concerns—that arose in the past and should be adequately considered before the U.S. Government undertakes the coordinated national research program this legislation would require.

The Administration respectfully requests that you defer further consideration of the bill pending the outcome of an inter-agency discussion of these issues that the Office of Science and Technology Policy (OSTP) would coordinate—with the Department of Justice on legal issues, with the Department of State on foreign policy implications, with the Departments of Defense and State on national security implications, and with pertinent research agencies to consider the reasons the U.S. Government previously halted its work in this area. At the conclusion of this review, the Administration would report back to you on the results of these discussions so you are fully apprised of all possible issues associated with authorizing a new Federal program on this topic.

Specifically, the Administration believes concerns in the following areas must be better understood:

- Local Political & Legal Ramifications

  —Because small scale weather modification (e.g., cloud seeding) may promote rain in one area to the detriment of another, weather modification could result in inter-state (including Indian Tribes) litigation or private citizen litigation against the modification programs.

  —The legal and liability issues pertaining to weather modification, and the potential adverse consequences on life, property, and water resource availability

resulting from weather modification activities, must be considered fully before the U.S. Government could take responsibility for this new research program.

- International and Foreign Policy Implications

  —Small and large scale (e.g., hurricane) weather modification efforts could benefit the United States to the detriment of other countries (such as Canada or Mexico).

  —Given global weather patterns, whether one country "owns" its weather so as to assert intra-border control with extra-border consequences, must be considered under present international conventions.

  —The manner in which such a program could benefit or harm the present U.S. positions on foreign policy matters, such as global warming/climate change, should also be considered.

- National Security Implications

  —The U.S. Government's previous weather modification programs were part of our Cold War history; restarting them today could promote (possibly hostile) foreign responses.

  —In 1978, the United States became a party to an international treaty banning the use of weather modification for hostile purposes. While modification for peaceful purposes is allowed, whether well-intentioned programs could be considered "hostile" and perceived to violate this ban should be considered.

- Research Issues

  —The Department of Commerce's National Oceanic and Atmospheric Administration's (NOAA) primary atmospheric and meteorological research focus is on improving weather forecasting, which has proven to save lives and property. NOAA abandoned weather modification activities some time ago in favor of other research areas that more directly relate to the agency's core mission and responsibilities.

  —Redirecting funding to focus on weather modification can shift funds away from other important programs such as research to improve weather forecasting capabilities for severe weather events and research to better understand climate variability and change.

In addition to discussing these concerns on an interagency basis, and in recognition of your interest in this area, OSTP would be willing to charter a study to address the above issues. This study would be conducted by the Science and Technology Policy Institute (STPI), a federally-chartered research and development center that provides objective, technical advice to OSTP. The study would address the history and current status of weather modification research. Such a study will help us understand the technical position of this field of science, the significance of the issues discussed above, and the field's historical context.

The Administration requests that you not move forward with your legislative proposal until a better understanding can be developed of the full range of possible implications.

Thank you for your consideration.

Sincerely,

JOHN H. MARBURGER, III,
Director.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. DANIEL K. INOUYE TO DR. JOSEPH H. GOLDEN

Weather Board

Question 1. What is this Board's legal and line of authority relationship to the Secretary of Commerce and the Administrator of NOAA?

Answer. There is no legal and line of authority relationship of the Board to the Secretary of Commerce and NOAA. However, a Subcommittee would be established under OSTP and a board of private advisors will support the Subcommittee's efforts. NOAA will be a Co-Chair of the Subcommittee with NSF.

Question 2. What is the legal and scientific basis for creating such a powerful entity?

Answer. This entity is being established to study the effectiveness of a weather modification program and would not establish direct authority to conduct operational weather modification.

Question 3. The establishment of this Board appears to place weather modification research above all other types of atmospheric research as a priority for funding within the Federal system. Why?

Answer. No, I do not believe the bill places weather modification research above any other type of atmospheric research within the Federal agencies. Further, one cannot divorce weather modification research from basic atmospheric research. One must not forget that a prerequisite for meaningful weather modification is that one must first understand the phenomenon being modified. Thus, weather modification research always adds to the body of knowledge of basic weather we already have now, resulting in better forecasts and warnings of most weather phenomena. I strongly believe that now is the time to begin a sustained Federal effort in weather modification research, not only to determine optimum conditions and appropriate technologies for winter snowpack and summer rainfall enhancement, but for studies of severe storm modification (including hurricanes and tornadoes) as well. I have no doubt that some of the most urgent weather modification research will directly benefit NWS/NOAA goals as well in short-term weather forecasts and warnings.

Question 4. Would this board have subpoena powers and the power to issue "rules," as is suggested by the bill?

Answer. No, I don't anticipate that the Board, in either bill, would have subpoena powers. Nor do I feel that it should issue "rules," as other groups like the ASCE already issue best-practice documents for weather modification operations. The Board should organize and coordinate a national Federal program in weather modification research and technology development, and recommend needed funding to accomplish these tasks (through the expert Subcommittee).

Question 5. Is the purpose of the Board to essentially create an independent agency dedicated to the promotion of weather modification research and distribution of grants? Please explain.

Answer. No, again, the Board and its Subcommittee of experts should develop a coordinated national program of research through existing Federal agencies, including especially NOAA, NSF, and NASA.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. E. BENJAMIN NELSON TO DR. JOSEPH H. GOLDEN

Legal Issues of Weather Modification

Has anyone considered the legal issues involved in weather modification? There is only a certain amount of moisture in the atmosphere; if artificial measures are used to make it rain in a particular location to relieve drought, for example, that water is diverted from another location where it would have ultimately fallen. This raises similar issues as water rights controversies, where rivers have been diverted to accommodate certain interests at the expense of others.

Question 1. Has the scientific community considered the legal implications of weather modification?

Answer. Yes, the scientific community has carefully considered the legal implications of weather modification for many years. One of my esteemed colleagues in the weather modification community (deceased) was Ray Jay Davis, a lawyer from Salt Lake City. My colleague, Dr. Tom DeFelice will include more details and some of Mr. Davis' writings on legal issues in his response to your question.

Question 1a. Shouldn't Congress be concerned that any government supported Weather Modification Board might support research and development of weather modifications without considering the legal implications?

Answer. I believe that the Board will be composed of a broad cross-section of public and private individuals who will act responsibly, with additional oversight by OSTP. Legal implications become most important in weather modification operations, but at this time, no operational seeding will be conducted by the Federal Government in any research supported by the bill. The Congress passed a Public Law in l971 that requires all operational weather modification projects in the U.S. to report details of their projects at least once a year to NOAA.

Question 2. Have you addressed the basic question of who owns the weather?

Answer. There is no sole ownership of the weather, therefore, any large-scale operational weather modification projects have always had to address both legal and environmental issues. For example, the NOAA/Navy joint hurricane modification Project STORMFURY had to produce an extensive study of possible environmental impacts prior to its commencement, and these were all documented in an EIS Report subjected to peer review. Currently, the Weather Modification Association cer-

tifies weather modification operators, and includes ethical and legal guidelines in the process.

Funding

I am concerned that there are a number of areas within weather research that are inadequately funded. For example, drought is of particular concern to my state right now. The National Drought Mitigation Center (NDMC) in Nebraska has only been in existence since 1995. Previously, no national initiative or program existed to monitor drought trends. The work at the NDMC in monitoring drought, not only in Nebraska, but nationwide, will help us mitigate and respond to its effects in a much more effective manner. This is only one of numerous programs addressing weather monitoring, mitigation, and response that is years behind where it could be.

Question 1. Should funding of new research on weather modification be a greater priority than research in the weather we already have now?

Answer. No, I do not believe either version of the bill places weather modification research above any other type of atmospheric research within the Federal agencies. One cannot divorce weather modification research from basic atmospheric research. One must not forget that a prerequisite for meaningful weather modification is that one must first understand the phenomenon being modified. Thus, weather modification research always adds to the body of knowledge of basic weather we already have now, resulting in better forecasts and warnings of most weather phenomenon. I strongly believe that now is the time to begin a sustained Federal effort in weather modification research, not only to determine optimum conditions and appropriate technologies for winter snowpack and summer rainfall enhancement, but for studies of severe storm modification (including hurricanes and tornadoes) as well. I have no doubt that some of the most urgent weather modification research will directly benefit NWS/NOAA goals as well in short-term weather forecasts and warnings.

Question 2. Shouldn't we ensure that existing research is adequately funded in order to protect commercial and governmental interests before making a commitment to support private research?

Answer. Yes, we should ensure adequate funding for Federal weather research. This bill will not make a commitment to direct private research in weather.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. BILL NELSON TO DR. JOSEPH H. GOLDEN

Funding

The Hurricane Research Division of NOAA's Office of Atmospheric Research has been inadequately funded for many years. As a result, research staff vacancies have gone unfilled, years of data have gone unanalyzed, and the science of hurricane prediction—especially with regard to intensity—is years behind where it could be.

Question 1. Should funding of new research on weather modification be a greater priority than research in the weather we already have now?

Answer. No, I believe that the two types of research are both needed and are not mutually exclusive. Weather modification research will certainly add to the body of knowledge of the weather we already have now. This research will be supportive and complementary. Many of the most critical research issues for weather modification involve technology and scientific questions that directly impact the short-term weather forecast and warning problems faced by my colleagues in the National Weather Service and the U.S. Military.

Question 2. Shouldn't we ensure that government hurricane research is adequately funded in order to protect lives before we make a commitment to support private research in weather research that has primarily only commercial applications?

Answer. Yes, we should ensure adequate funding for government research. I am knowledgeable about the need for hurricane research. This bill would not make a commitment to support private research in weather.

I believe that the premise of this question is incorrect, because the bulk of the research and funding to carry it forward would occur in the Federal weather labs and the universities. The weather modification research would have applications extending far beyond "commercial applications." The outputs of this research would also have immediate payoffs to helping Federal agencies reach their GPRA goals in improved observations, modeling and improved forecast/warning performance for NWS. For example, improved 3–D models for determining transport of seeding materials into cloud systems could also be used for tracking bioterrorism releases in populated areas and for improved forecasts of air quality.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. DANIEL K. INOUYE TO DR. THOMAS P. DEFELICE

Weather Board

Question 1. What is this board's legal and line of authority relationship to the Secretary of Commerce and the Administrator of NOAA?

Answer. Recent bill mark up discussions call for a permanent subcommittee (Weather Modification) within the Office of Science and Technology, who's chair would report directly to the President's Science Advisor.

Question 2. What is the legal and scientific basis for creating such a powerful entity?

Answer. There are multiple reasons to take everyday basic and applied science knowledge, combine it with latest technologies and apply them creating not only improved science and technology, but also tools that better serve and support the people. There is no funding to accomplish said, and time is running out. This subcommittee is necessary to study and verify the effectiveness and reliability of the science of weather modification.

Question 3. The establishment of this board appears to place weather modification research above all other types of atmospheric research as a priority for funding within the Federal system. Why?

Answer. No, the establishment of this board does not place weather modification research above all other types of research, Research related to weather modification more visibly serves societal needs (such as providing more water for reservoirs, energy generation or more sunshine for mental wellbeing, energy storage, reducing the destructive forces associated with hurricanes, or drought mitigation), and also provides data for the research already underway.

Question 4. Would this board have subpoena powers and the power to issue "rules," as is suggested by the bill?

Answer. No, the Board will only report to the Subcommittee which will be comprised of Federal agencies.

Question 5. Is the purpose of the Board to essentially create an independent agency dedicated to the promotion of weather modification research and distribution of grants? Please explain.

Answer. No, the Board will report suggestions and provide answers to technical questions issued by the subcommittee.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. E. BENJAMIN NELSON TO DR. THOMAS P. DEFELICE

Question 1. Has anyone considered the legal issues involved in weather modification? There is only a certain amount of moisture in the atmosphere; if artificial measures are used to make it rain in a particular location to relieve drought, for example, that water is diverted from another location where it would have ultimately fallen.

Answer. Yes there is a certain amount of moisture in the atmosphere and most of it naturally stays there in some form or another. Very little atmospheric moisture falls out as precip (rain) on a global average basis. The precipitation efficiency of a thunderstorm is only about 20 percent, meaning 80 percent of the moisture associated with it remains in the atmosphere. I can provide the reference.

Cloud seeding does not divert rain from falling in one place in favor of another (or in other words, cloud seeding does not rob Peter of rain to 'water' Paul, it provides a little more rain to Peter and more rain to Paul than he would have received naturally). Clouds have been observed to contain plenty of moisture, even during the early months of a drought-period. Clouds just don't always possess a natural precipitation initiation mechanism (virga—precipitation that doesn't reach the ground—is not an example of a viable precipitation process, but may occur). The absence of a viable precipitation process also happens frequently in the areas surrounding deserts (drought regions).

Cloud seeding applied to such clouds, under the right atmospheric conditions, provides the trigger to initiate a viable precipitation process. So cloud seeding extends the area of precipitation beyond what nature is able to provide. This is analogous to receiving a flu shot to make our immune system more viable during flu season. It is mostly not true that getting a flu shot gives us the flu. Not getting the flu shot generally means getting the flu.

This raises similar issues as water rights controversies, where rivers have been diverted to accommodate certain interests at the expense of others.

Question 2. Has the scientific community considered the legal implications of weather modification?

Answer. The legal implications of weather modification are well documented (e.g., Ray Jay Davis, lawyer (deceased); Academic Press book on Weather Modification by Arnett Dennis 1981; American Society Civil Engineers (ASCE), Manual of Professional Practice for precipitation enhancement, 2nd Edition, and the ASCE standard practice documents on hail suppression, precipitation augmentation, and supercooled fog dispersal seeding operations).

The scientists who regularly attend weather modification association meetings are familiar with these implications, and efforts have been underway to reach others. The Weather Modification Association Public Information Committee Chair will be happy to provide such documents to the Senator.

Question 3. Shouldn't Congress be concerned that any government supported Weather Modification Board might support research and development of weather modifications without considering the legal implications?

Answer. Legal implications mostly apply to operations, and operational seeding will not be conducted by the Federal Government under Senator Hutchison's bill. The board is comprised of people who have direct experience with weather modification activities.

Question 4. Have you addressed the basic question of who owns the weather?

Answer. This is currently left to the States. Under this bill any activity to modify the weather would have to address legal and environmental issues before it commenced since all would have a stake in the deliverable.

Funding

I am concerned that there are a number of areas within weather research that are inadequately funded. For example, drought is of particular concern to my state right now. The National Drought Mitigation Center (NDMC) in Nebraska has only been in existence since 1995. Previously, no national initiative or program existed to monitor drought trends. The work at the NDMC in monitoring drought, not only in Nebraska, but nationwide, will help us mitigate and respond to its effects in a much more effective manner. This is only one of numerous programs addressing weather monitoring, mitigation, and response that is years behind where it could be.

Question 1. Should funding of new research on weather modification be a greater priority than research in the weather we already have now?

Answer. No, but funding weather modification research can lead to additional technologies that more visibly serve societal needs, such as providing more water for reservoirs, energy generation or more sunshine for mental wellbeing, energy storage, reducing the destructive forces associated with hurricanes, or drought mitigation.

If science and technology expenditures can be explicitly directed toward resolving a societal issue, it will make it easier to obtain public support, as society will see and appreciate that their taxes are being used to help resolve issues they face.

Question 2. Shouldn't we ensure that existing research is adequately funded in order to protect commercial and governmental interests before making a commitment to support private research?

Answer. Private research support for weather modification does not exist. Thus research related to weather modification requires some research to understand what is to be modified. So, funding technology development and their application also funds the existing research. The direct benefits of funding weather modification research could be realized in the Departments of Commerce, Interior, and Homeland Security (tracking and removal of bioterrism agents).

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. BILL NELSON TO DR. THOMAS P. DEFELICE

Funding

The Hurricane Research Division of NOAA's Office of Atmospheric Research has been inadequately funded for many years. As a result, research staff vacancies have gone unfilled, years of data have gone unanalyzed, and the science of hurricane prediction—especially with regard to intensity—is years behind where it could be.
Question 1. Should funding of new research on weather modification be a greater priority than research in the weather we already have now?

Answer. No, but funding weather modification research can lead to additional technologies that more visibly serve societal needs, such as providing more water

for reservoirs, energy generation or more sunshine for mental wellbeing, energy storage, reducing the destructive forces associated with hurricanes, or drought mitigation.

It was envisioned that the NOAA Hurricane Research Division (HRD) could play a significant role in weather modification research, since HRD models represent the best available for simulating realistic hurricanes. The unanalyzed data from previous hurricane research are useful for conducting crude verification of select hurricane model outputs.

Question 2. Shouldn't we ensure that government hurricane research is adequately funded in order to protect lives before we make a commitment to support private research in weather research that has primarily only commercial applications?

Answer. Yes, government hurricane research must be adequately funded, along with all weather system research. There is *no known funding authorization for private research.*

RESPONSE TO WRITTEN QUESTIONS SUBMITTED TO MICHAEL GARSTANG, PH.D.

Priorities and Funding of Atmospheric Research

Questions from Hon. E. Benjamin Nelson:

1. Should funding of new research on weather modification be a greater priority than research in the weather we already have now?

2. Shouldn't we ensure that existing research is adequately funded in order to protect commercial and governmental interests before making a commitment to support private research?

Questions from Hon. Bill Nelson:

1. Should funding of new research on weather modification be a greater priority than research in the weather we already have now?

2. Shouldn't we ensure that government hurricane research is adequately funded in order to protect lives before we make a commitment to support private research in weather research that has primarily only commercial applications?

Questions from Hon. Daniel K. Inouye:

1. What is this Board's legal and line of authority relationship to the Secretary of Commerce and the Administrator of NOAA?

2. What is the legal and scientific basis for creating such a powerful entity?

3. The establishment of this board appears to place weather modification research above all other types of atmospheric research as a priority for funding within the Federal system. Why?

4. Would this Board have subpoena powers and the power to issue "rules," as is suggested by the bill?

5. Is the purpose of the Board to essentially create an independent agency dedicated to the promotion of weather modification research and distribution of grants? Please explain.

Answers to questions 3 and 5 (questions 1, 2, and 4 were beyond the Scope of the NRC Report).

The NRC report documents the decline in funding for research in weather modification over the past 3 decades. Federal funding of weather modification research declined by the 1990s to less than $0.5M/year.

The NRC report points out the paradox between

1. funding (largely by States) of unverified weather modification methods to address critical needs for water and reduction of damage (hail) but failure to fund the research needed to understand and improve these methodologies.

2. substantial application of research funds directed at understanding and defining the implications of inadvertent weather modification (global warming) but failure to employ resources that would address advertent weather modification despite the fact that many of the basic scientific principles underly both unintentional and intentional weather modification.

The NRC report emphasizes the fact that over the past 30 years enormous strides have been made in technology enabling processes critical to *all* weather to be observed, recorded, assimulated and modelled. Explicit attack upon critical physical processes such as the formation of a raindrop or a hail stone is now possible. Such a directed and sustained effort to remove obstacles to progress would pay dividends not only in weather modification but in many areas of the weather.

For example, one of the greatest difficulties facing a weather forecaster is the prediction of the intensity and amount of the expected rain and hence flooding and other damage. Understanding the microphysics leading to rain can be significantly

enhanced by carrying out controlled weather modification experiments. This understanding of precipitation would contribute directly to furthering our ability to predict the intensifying or weakening of a hurricane.

The NRC report recommends a very directed research effort which would address a series of obstacles in understanding critical atmospheric processes. Such an effort would benefit a broad spectrum of applications of weather science.

The NRC report explicitly advises against the application of Federal research resources to rain enhancement or hail reduction experiments until the critical questions blocking progress have been addressed.

Finally, the NRC report points to the need and responsibility to address questions of water needs, severe storm damage ranging from hail and lightning to wind and water damage. The capability now exists to determine whether and to what extent humans are capable of exercising control over the weather. Unless a concerted and sustained effort is mounted by all of those responsible such questions will remain unanswered.

Legal Implications of Weather Modification

Questions from Hon. E. Benjamin Nelson:

1. Has the scientific community considered the legal implications of weather modification?

2. Shouldn't Congress be concerned that any government supported Weather Modification Board might support research and development of weather modifications without considering the legal implications?

3. Have you addressed the basic question of who owns the weather?

Answer:

The NRC report recognized the importance of weather modification research to society including legal implications. The NRC Committee's terms of reference were confined to addressing the current and future state of weather modification research.

The NRC report does, however, point out that efforts in rainfall enhancement are directed at the redistribution and efficient use of existing water vapor supplies in the atmosphere. Intervention could produce rain where needed without "robbing Peter to pay Paul". Research and operations which have shed light on this question suggest instead that "extra area" effects extend rather than limit the effects of rainfall enhancement.